ancestry. He supports his colleague, Dr. W. D. Matthew—in opposition to the view generally held in this country—in regarding the lower jaw of Eoanthropus as that of a Piltdown chimpanzee associated by a curious chance with the Piltdown man in a pocket of gravel. We look forward to the appearance of parts iii. and iv. of Dr. Gregory's studies, in which he proposes to review the phylogenies of the catarrhine, or Old World, monkeys, and platyrrhine, or New World, monkeys and Lemuroids.

HEREDITARY CHARACTERS IN RELATION TO EVOLUTION.

PROF H. S. JENNINGS, of the Johns Hopkins University, delivered a lecture on March 15 before the Washington Academy of Sciences on "Observed Changes in Hereditary Characters in Relation to Evolution." This lecture, published in the Journal of that Academy (vol. vii., No. 10), consists of a discussion on the factors of evolution of such great interest that we have decided to print an abridgment so that readers of NATURE may have the opportunity of studying and appreciating his arguments as set forth in his own words. The older school of biologists in this country will doubtless welcome Prof. Jennings's brilliant and ingenious interpretation of the recent work of American zoologists on genetics, so as to support the Darwinian interpretation of the evolutionary process. Prof. Jennings's criticism of Mr. Bateson's British Association address (1914) leaves the reader in doubt whether he has appreciated the view that the "loss and disintegration" in the germ-plasm are conceived by Bateson as the shedding of successive inhibitory factors the withdrawal of which leaves the hypothetical fundamental germ-complex free to produce an increasingly complex result in the developing organism.

The problem of the method of evolution is one which the biologist finds it impossible to leave alone. Can we bring the facts which experimental work has brought out into relation with the method of evolution?

What we may call the first phase of the modern experimental study of variation is that which culminated in the establishment of the fact that most of the heritable differences observed between closely related organisms—between the members of a given species, for example—are not *variations* in the sense of alterations; are not active *changes* in constitution, but are permanent diversities; they are static, not dynamic. This discovery was made long ago by the Frenchman Jordan; but, as in the case of Mendelism, science ignored it and pursued cheerfully its false path until the facts were rediscovered in recent years. All thorough work has led directly to this result: that any species or kind of organism is made up of a very great number of diverse stocks, differing from each other in minute particulars, but the diversities inherited from generation to generation. This result has in recent years dominated all work on the occurrence of variations; on the effects of selection; on the method of evolution. The condition is particularly striking in organisms reproducing from a single parent, so that there is no mixing of stocks; I found it in a high degree in organisms of this sort which I studied. Thus the infusorian Paramecium I found to consist of a large number of such heritably diverse stocks, each stock showing within itself many variations that are not heritable.[1] *Difflugia corona* shows the same condition in a marked degree.[2] A host of workers have found similar conditions in all sorts of organisms. It led to the idea of the genotype (Johannsen), as the permanent germinal constitution of any given individual; it supported powerfully the conception of Mendelism as merely the working out of recombinations of mosaic-like parts of these permanent genotypes. The whole conception is in its essential nature static; alteration does not fit into the scheme.

This discovery seemed to explain fully all the observed effects of selection within a species; but gave them a significance quite the reverse of what they had been supposed to have. It seemed to account for practically all the supposed variations that had been observed; they were not variations at all, in the sense of steps in evolution; they were mere instances of the static condition of diversity that everywhere prevails. Jordan, the devout original discoverer of this condition of affairs, maintained that it showed that organisms do not really vary; that there is no such process as evolution; and, indeed, this seems to be the direct logical conclusion to be drawn.

Now, this multiplicity of diverse stocks really represents the actual condition of affairs, *so far as it goes*. Persons who are interested in maintaining that evolution *is* occurring, that selection *is* effective, and the like, make a very great mistake in denying the existence of the condition of diversity portrayed by the genotypists. What they must do is to accept that condition as a foundation, then show that it is not final; that it does not proceed to the end; that the diverse existing stocks, while heritably different as the genotypists maintain, may also change and differentiate, in ways not yet detected by their discoverers.

But, of course, most of the adherents of the "orthodox genotype theory" do not maintain, with their first representative Jordan, that no changes occur. Typically, they admit that *mutations* occur; that the genotype may at rare intervals transform, as a given chemical compound may transform into another and diverse compound. We all know the typical instances: the transforming mutations of Œnothera; the bud variations that show in a sudden change of colour or form in plants; the dropping out of definite Mendelian units in Drosophila and elsewhere; the transformation of particular Mendelian units into some other condition.

So much, then, may serve as an outline of a prevailing theory; organisms forming a multitude of diverse strains with diverse genotypes; the genotype a mosaic of parts that are recombined in Mendelian inheritance; selection a mere process of isolating and recombining what already exists; large changes occurring at rare intervals, through the dropping of bits of the mosaic, or through their complete chemical transformation; evolution by saltations.

Certain serious difficulties appear in this view of the matter; I shall mention merely two of them, for their practical results. One is the very existence of the minutely differing strains, which forms one of the main foundations for the genotype theory. How have these arisen? Not by large steps, not by saltations, for the differences between the strains go down to the very limits of detectibility. On the saltation theory, Jordan's view that these things were created separate at the beginning seems the only solution.

Secondly, to many minds there appears to be an equally great difficulty in the origin by saltation of complex adaptive structures, such as the eye. I shall not analyse this difficulty, but merely point to it and to the first one mentioned, as having had the practical effect of keeping many investigators persistently at work looking for something besides saltations as a basis for evolution; looking for hereditary changes that would permit a continuity in transformation.

Where reproduction is from a single parent we meet the problem of inheritance and variation in its simplest form; for there is nothing which complicates genetic problems so enormously as does the continual mixing of diverse stocks in biparental inheritance. In uniparental reproduction we have but one genotype to deal with; we can be certain that no hereditary characters are introduced from outside that genotype.

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[1] Jennings, 1908-11. (See Bibliography.)

[2] Jennings, 1916. (See Bibliography.)

To hope for results on the problem in which we are interested, we must resolve to carry on a sort of second degree research, as it were. We must take a single stock—choosing an organism that is most favourable for such work—then proceed to a most extensive and intensive study of heredity, of variation, and of the effects of selection for long periods within such a stock.

Such an organism, most favourable from all points of view, I found in the rhizopod *Difflugia corona.* It has numerous distinctive characters, all congenital, all inherited in a high degree, yet varying from parent to offspring also; none of these characters changed by growth or environmental action during the life of the individual.

Long-continued work showed that a single strain of this animal, all derived by fission from a single parent, does differentiate gradually, with the passage of generations, into many hereditarily diverse strains. The important facts about the hereditary variations and their appearance are the following:—

(1) Hereditary variations arose in some few cases by rather large steps or "saltations."

(2) But the immense majority of the hereditary variations were minute gradations. Variation is as continuous as can be detected.

(3) Hereditary variation occurred in many different ways, in many diverse characters. There was no single line of variation followed exclusively, or in the overwhelming majority of cases.

(4) It gave rise to many diverse combinations of characters: large animals with long spines; small animals with long spines; large animals with short spines; small animals with short spines; and so on. Any set of characters might vary independently of the rest.

(5) The hereditary variations which arose were of just such a nature as to produce from a single strain the hereditarily different strains that are found in nature.[3]

I judge that if the intermediate strains were killed, the two most diverse strains found in Nature might well be classed as different species, although the question of what a species is must be left to the judgment or fancy of the individual.

How do these results compare with those found by other men? If we take a general survey, we find the following main classes of cases:—

(1) First, we have the mutations of Œnothera and its relatives: large transformations occurring suddenly.

(2) Secondly, we have a large miscellaneous collection of mutations observed in various classes of organisms: "bud variations," dropping out of unit factors, and the like—all definite saltations, but not genetically fully analysed.

(3) In Drosophila as studied by Morgan and his associates, we have the largest and most fully analysed body of facts which we possess with respect to changes in hereditary character in any organism. The changes here are pictured as typical saltations; but of these I shall speak further.

(4) In palæontology, as the results are presented in recent papers by Osborn,[4] the evidence is for evolution by minute, continuous variations which follow a single definite trend.

(5) Finally, we have the work in biparental inheritance from Castle and his associates[5]; this gives evidence for continuous variation, not following a single necessary trend, but guided by external selection.

Furthermore, we discover in our survey that there are at least two well-marked controversies in flame at the present time:—

First, we have the general controversy between, on one hand, those who are mutationists and adherents of the strict genotype view; on the other, those who, like Castle, believe that we observe continuous hereditary variations in the progress of biparental reproduction. The mutationists attempt to show that the apparent gradual modification of characters observed in breeding is in reality a mere working out of Mendelian recombinations.

Secondly, we have a somewhat less lively controversy between the genotypic mutationists and the palæontological upholders of evolution by continuous variation.

Now let us look briefly into the points at issue in the controversy between the "genotypic mutationists" and the upholders of gradual change during biparental inheritance.

Castle finds that in rats he can, by selection, gradually increase or decrease the amount of colour in the coat, passing by continuous stages from one extreme to the other. As to this, he holds two main points:—

(1) The change is an actual change in the hereditary characteristic of the stock; not a mere result of the recombination of Mendelian factors. This is the general and fundamental point at issue.

(2) More specifically, he holds it to be an actual change in a single-unit factor; this single factor changes its grade in a continuous and quantitative manner.

On the other side, the critics of these views maintain that the changes shown are not actual alterations in the hereditary constitution at all, but are mere results of the recombinations of Mendelian factors. And specifically, they find a complete explanation of such results as those of Castle in the hypothesis of *multiple modifying factors.* There is conceived to be a single "main factor" which determines whether the "hooded pattern" shall, or shall not, be present. In addition to this there are a considerable number of "modifying factors" which, when the "hooded pattern" is present, increase or decrease the extent of pigmentation. When many of the positive factors of this sort are present, the rat's coat has much pigment; when fewer are present the extent of pigment is less, and so on. The process of changing the extent of pigmentation by selection consists, according to this view, merely in making diverse combinations of these factors, by proper crosses.

This same explanation is applied to a great variety of cases. Castle had carried the war into the enemy's country by predicting (or at least suggesting) that the so-called unit characters in Drosophila would be found to be modifiable through selection.[6] Later research by MacDowell (1915), Zeleny and Mattoon (1915), Reeves (1916), Morgan (1917), and Sturtevant (1917) actually verified this prediction; it has indeed been found that the Drosophila mutations can be modified by selection. Again, the mutationists counter the blow with their explanation of multiple modifying factors, which are segregated in the process of selection; and they give some real evidence that such is actually the case. What I am going to do is to abandon the ground that Castle would defend, proceed directly into the territory of the enemy, accept the conditions met there, then see where we come out in relation to the nature of variation, the effects of selection, and the method of evolution.

In no other organism have heritable variations been studied so thoroughly as in Drosophila, and no other body of men have been more thoroughgoing upholders of mutationism and of the multiple factor explanation of the effects of selection than the students of Drosophila—Morgan and the others. We may therefore turn to the evidence from Drosophila with confidence that it will be presented with fairness to the mutationist point of view. We shall first ask (1) what we learn from the work on Drosophila as to the possibility of finding finely graded variations in a single unit character. Next we shall inquire (2) as to the relation of the assumed modifying factors to changes in hereditary constitution; to the nature of the effects of selection.

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[3] The full account of this work is given in Jennings, 1916. (See Bibliography.)

[4] Osborn, 1912, 1915, 1916. (See Bibliography.)

[5] Castle, 1915 *a*, 1916, 1916 *a*, 1916 *b*, 1917; Castle and Phillips, 1914, etc. (See Bibliography.)

[6] Castle, 1915, p. 39. (See Bibliography.)

(*To be continued.*)

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Mr. F. C. Bartlett and Mr. G. M. Bennett have been elected to fellowships at St. John's College. Mr. Bartlett, who was placed in the first class in the Moral Sciences Tripos, 1914, is assistant in experimental psychology, and is acting as interim director of the psychological laboratory during the absence of the director. Mr. Bennett was placed in the first class of the Natural Sciences Tripos, both in Part I. in 1914 and in Part II. (chemistry) in 1915.

LEEDS.—The University has received with great regret the resignation by Prof. A. S. Leyton of the chair of pathology and bacteriology in the University. In accepting this resignation, the University Council has taken the opportunity of recording its high appreciation of the valuable services which Prof. Leyton rendered to the University during his tenure of the chair.

A COURSE of eight lectures on the philosophy of mathematics is being given this term by the Hon. Bertrand Russell at Dr. Williams's Library, Gordon Square, W.C.1. The lectures (of which the first was delivered on Tuesday, October 30) are given on Tuesdays at 5 p.m. The present course, which deals with the theory of order, cardinal numbers, and formal deduction, will probably be followed after Christmas by one on the philosophy of the proposition. Applications for tickets should be made to Miss D. Wrinch, Girton College, Cambridge.

THE recently established Department of Technical Optics of the Imperial College at South Kensington has now begun its work. It will be remembered that on the initiative of the London County Council a general scheme for providing instruction in this highly important national work was agreed upon by the several parties concerned in the early part of the year when an Advisory Committee to the County Council representative of the trade, the workers, and other interests concerned was appointed, under the chairmanship of the Rt. Hon. A. H. Dyke Acland. An important part of the scheme was the establishment of the above department, which is administered under the governors of the college by the same committee. In June Prof. F. J. Cheshire was appointed director of the new department; in July Prof. A. E. Conrady was appointed to the chair of optical design, and other subordinate appointments are in hand. During the summer two courses of lectures were given on the designing and computing of telescope systems, and attended by sixty-six students, of whom forty-two came direct from the workshop—a gratifying indication of the recognition by the manufacturers of the importance of this work. About twelve of these were men of academic distinction. The Ministry of Munitions, the National Physical Laboratory, the Royal Observatory, and Woolwich Arsenal were well represented. This session well-attended courses are being given in optical designing and computing, practical optical computing, the construction, theory, and use of optical measuring instruments, theory of the microscope, and microscope technique. Every effort is thus being made to meet the more immediately urgent demands arising in connection with the war. A complete curriculum for optical students will be introduced as soon as the exigencies of the time permit.

THE current issue of the *Quarterly Review* includes two contributions on educational subjects. One, by Mr. Edward Porritt, not only reviews the condition of agricultural education in the United States, but also provides an interesting historical survey of the steps taken to bring the work of the Department of Agriculture to its present high degree of efficiency. The Department of Agriculture at Washington has been a department of first rank in the executive branch of the Government of the United States—a department presided over by a Cabinet Minister—since 1889. In the fiscal year 1916–17 approximately 6,800,000*l*. was being expended by the U.S. Government on the department, on the agricultural colleges and experiment stations, and on extension work, the object of all these branches of the work being to improve all departments of farm economy, to ameliorate conditions on the farms and in the farm homes, and thereby to retain in rural pursuits the men, women, and children who are now on the six million farms of the United States. Mr. J. E. G. de Montmorency writes on national education and national life, and shows in a convincing manner that much useful guidance can be obtained from history in considering current suggestions for educational reform. One of our earliest historical documents, he tells us, for example, is an edict of the Emperor Gratian regulating the salaries of teachers. The proposals of Mr. Fisher's Education Bill are examined in the light of the experience of previous centuries, and after his criticisms Mr. de Montmorency comes to the conclusion:—"It would be a sad thing if a great scheme of educational reconstruction, which at last brings to the doors of the people the larger hope that is essential to a great democracy, were to fail because, in a comparatively small matter of money, the Government lacked that courage which is needful for the conduct of peace as it is for the prosecution of war."

ON October 18 the President of the Board of Education received an influential deputation representative of the North-East Coast Institution of Engineers and Shipbuilders and other technical societies and educational interests in the same district. It will be remembered (NATURE, August 23, vol. xcix., p. 519) that this institution has elaborated an excellent scheme for the training of apprentices, and the object of the deputation, which was headed by the Duke of Northumberland, was to lay before Mr. Fisher its reasoned opinion regarding the organisation of junior day technical schools. The most suitable school for the prospective engineer is of this type, and the institution has already demanded that adequate provision of these schools should be made in the North-East Coast area, which has about 14,000 marine engineering and shipbuilding apprentices, and that these schools should be regarded as in no sense inferior to secondary schools. Mr. Rowell referred in detail to the Board's regulations for junior day technical schools, and expressed the view that the declaration in the regulations that they were "not intended to promote the establishment of courses planned to furnish a preparation for the professions, the universities, or higher full-time technical work" was open to grave exception, as viewing the work of such a school as lying within a blind-alley. The point was, surely, one of spirit rather than of administration, for he could not imagine that the